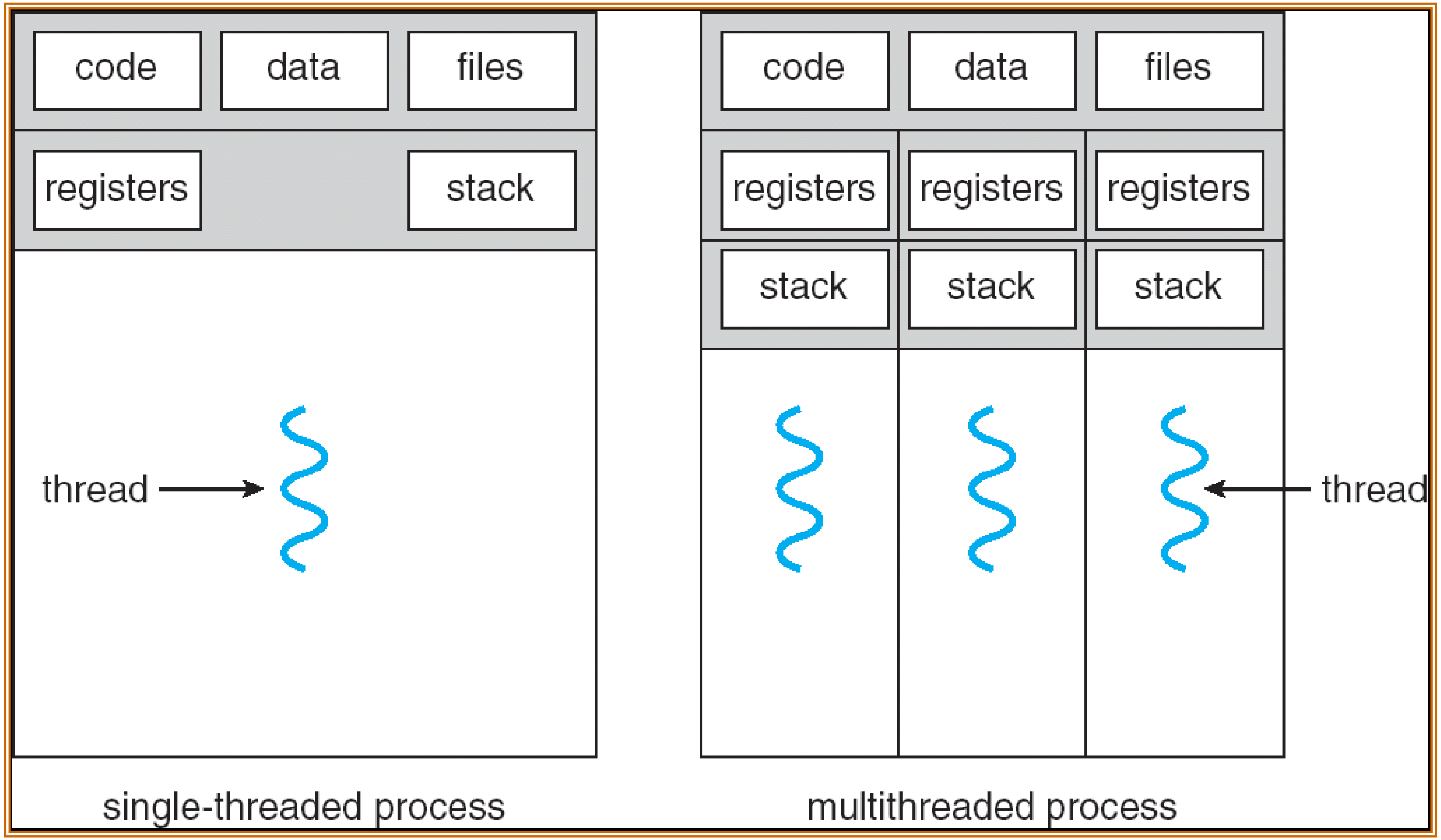
I.-C. Lin, Assistant Professor. Textbook: Operating System Concepts 8ed

CHAPTER 4: MULTITHREADED PROGRAMMING

Chapter 4: Multithreaded Programming

- Overview
- Multithreading Models
- Thread Libraries
- Threading Issues
- Operating-System Examples

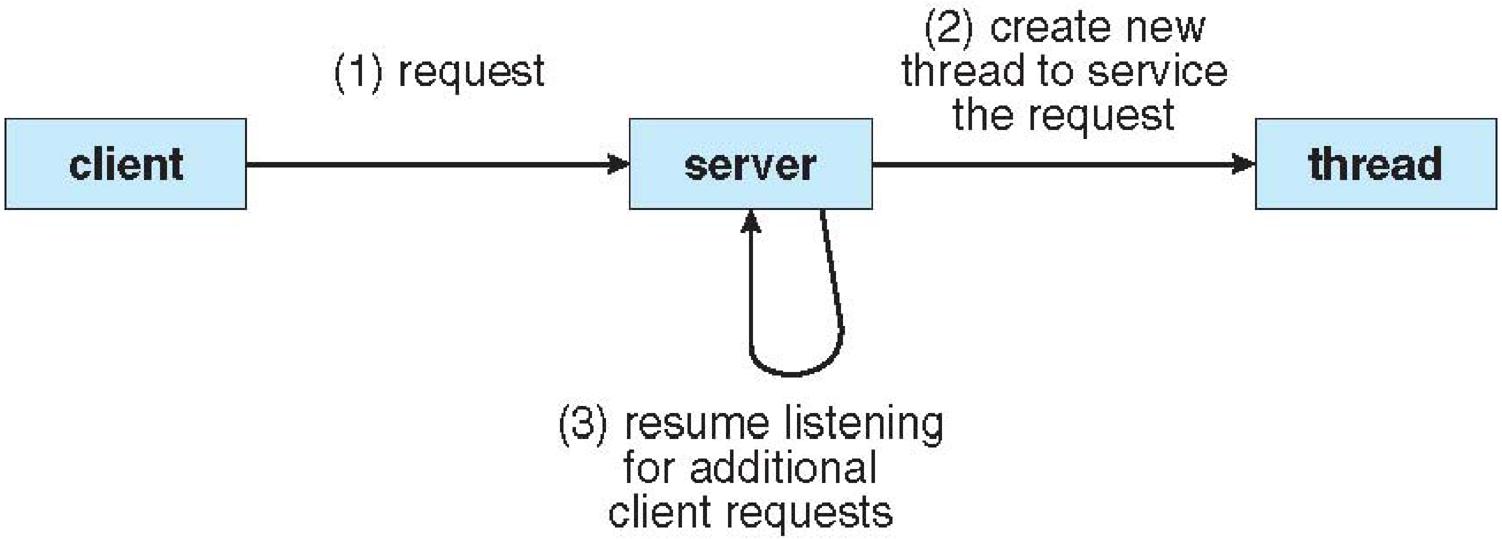
Single and Multithreaded Processes



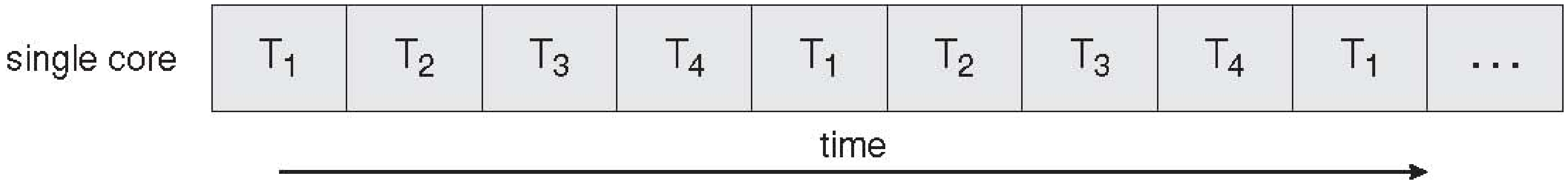
Benefits

- Responsiveness
- Resource Sharing
- Economy
- Utilization of MP Architectures

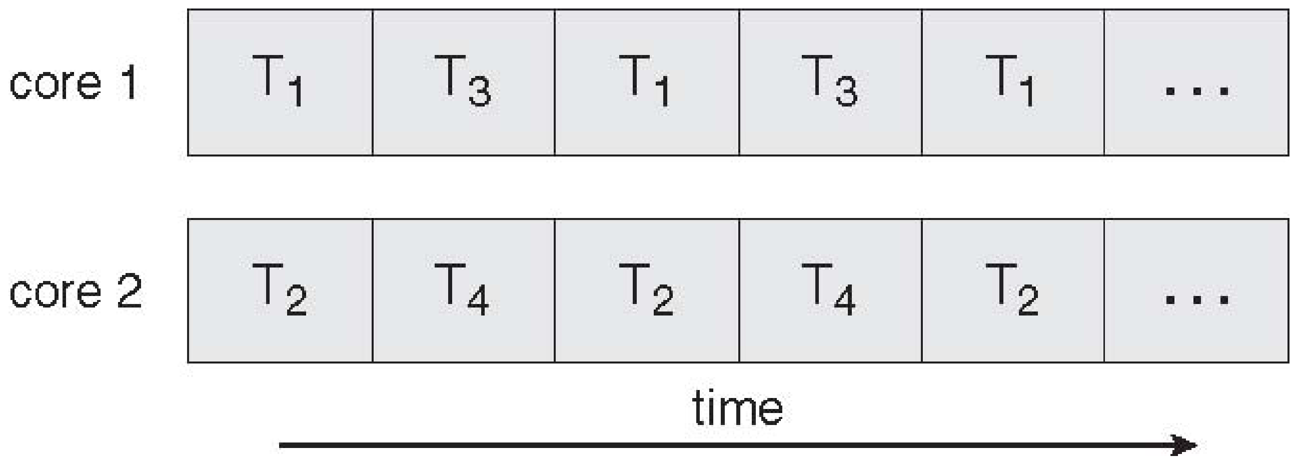
Multithreaded Server Architecture



Concurrent Execution on a Single-core System



Parallel Execution on a Multicore System



User Threads

- Thread management done by user-level threads library

- Three primary thread libraries:
  - POSIX Pthreads
  - Win32 threads
  - Java threads

Kernel Threads

- Supported by the Kernel
- Examples
  - Windows XP/2000
  - Solaris
  - Linux
  - Tru64 UNIX
  - Mac OS X

Multithreading Models

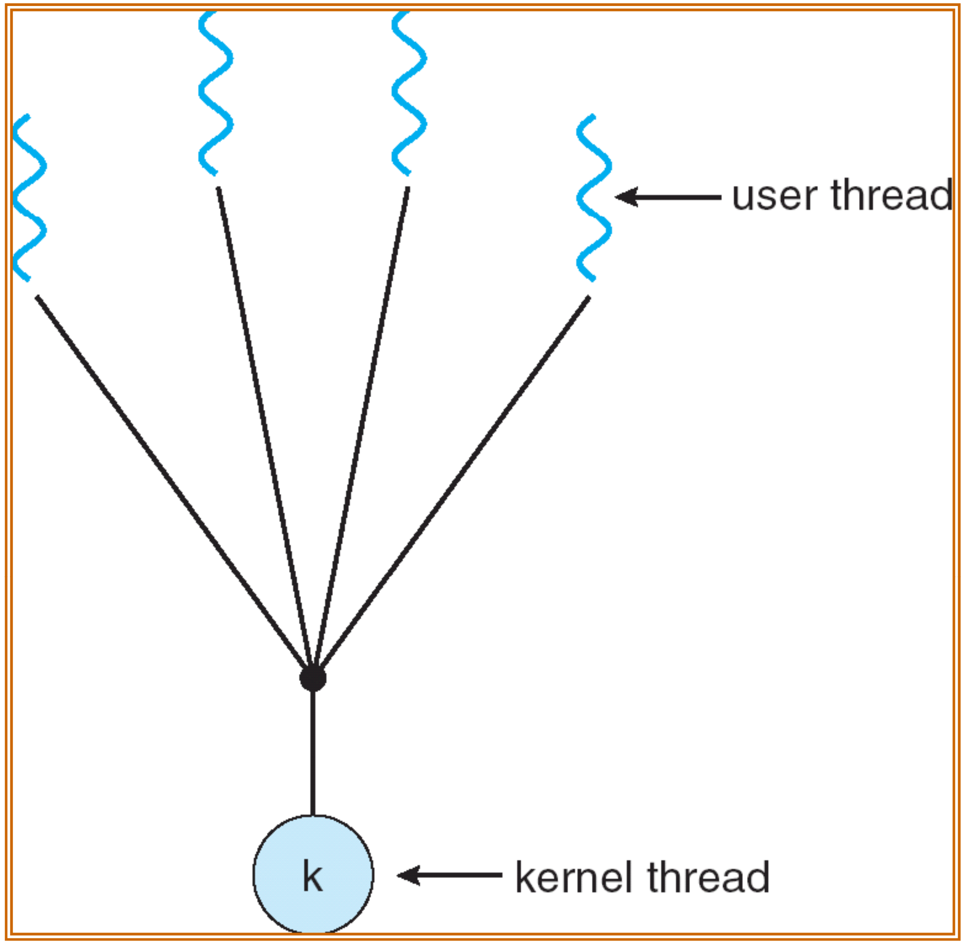
- Many-to-One
- One-to-One
- Many-to-Many

Many-to-One

- Many user-level threads mapped to single kernel thread

- Examples:
  - Solaris Green Threads
  - GNU Portable Threads

Many-to-One Model

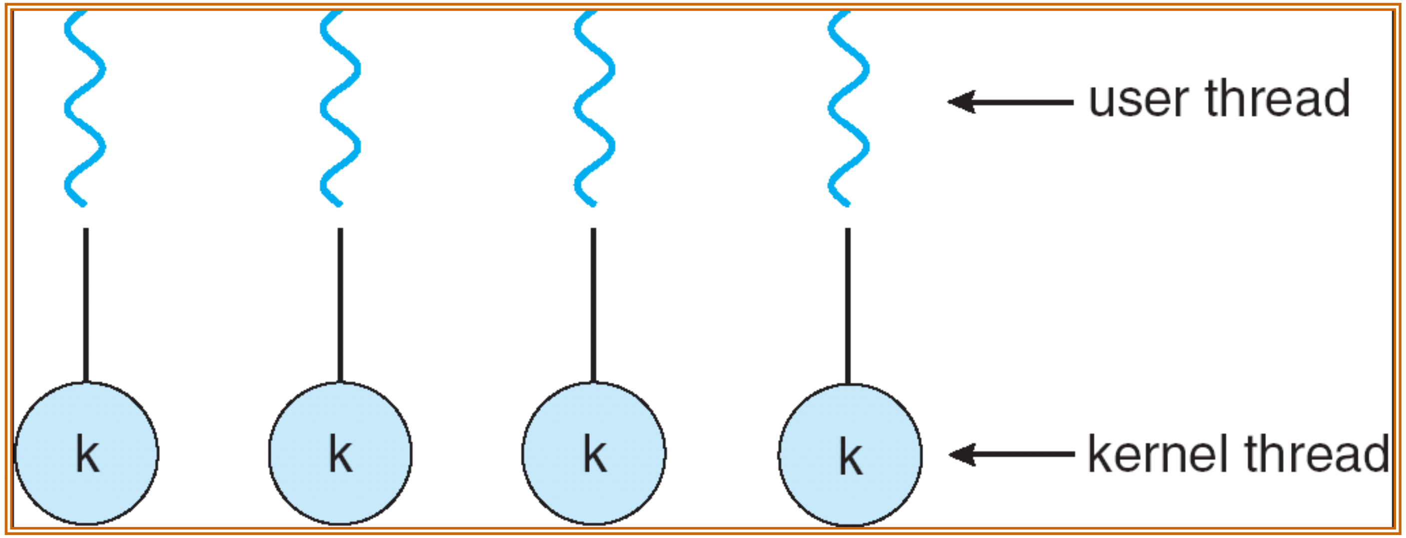


One-to-One

- Each user-level thread maps to kernel thread

- Examples
  - Windows NT/XP/2000
  - Linux
  - Solaris 9 and later

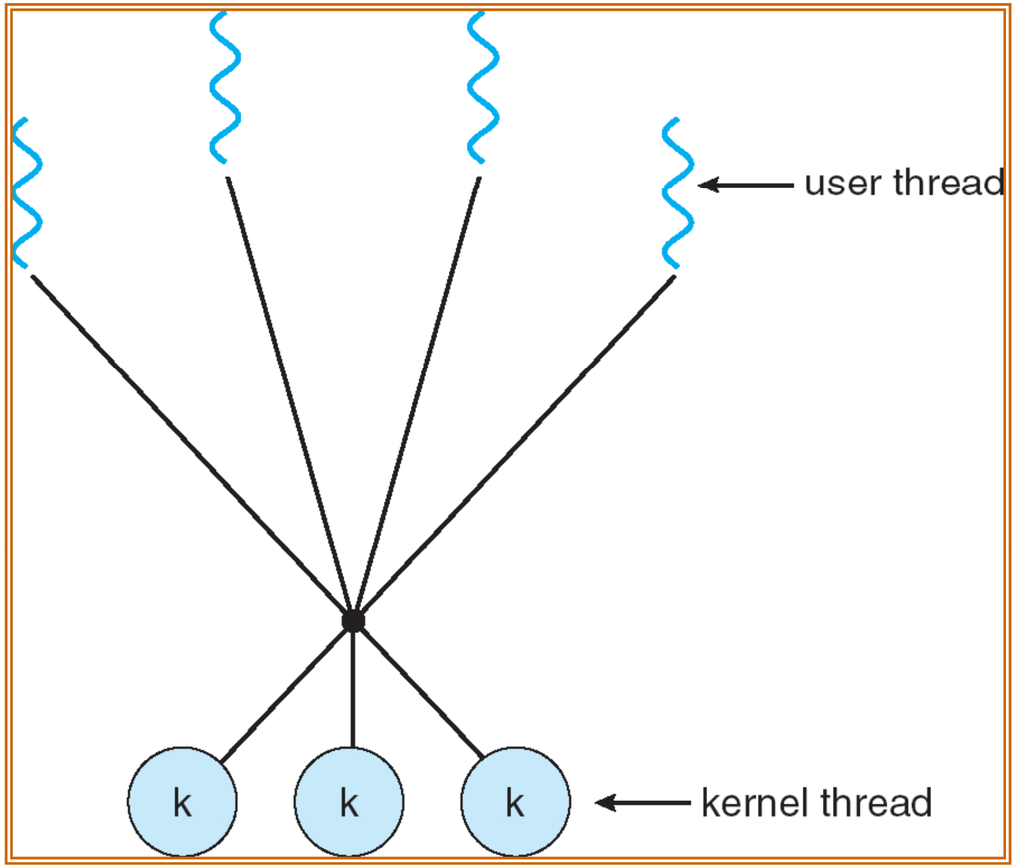
One-to-one Model



Many-to-Many Model

- Allows many user level threads to be mapped to many kernel threads
- Allows the operating system to create a sufficient number of kernel threads
- Solaris prior to version 9
- Windows NT/2000 with the *ThreadFiber* package

Many-to-Many Model

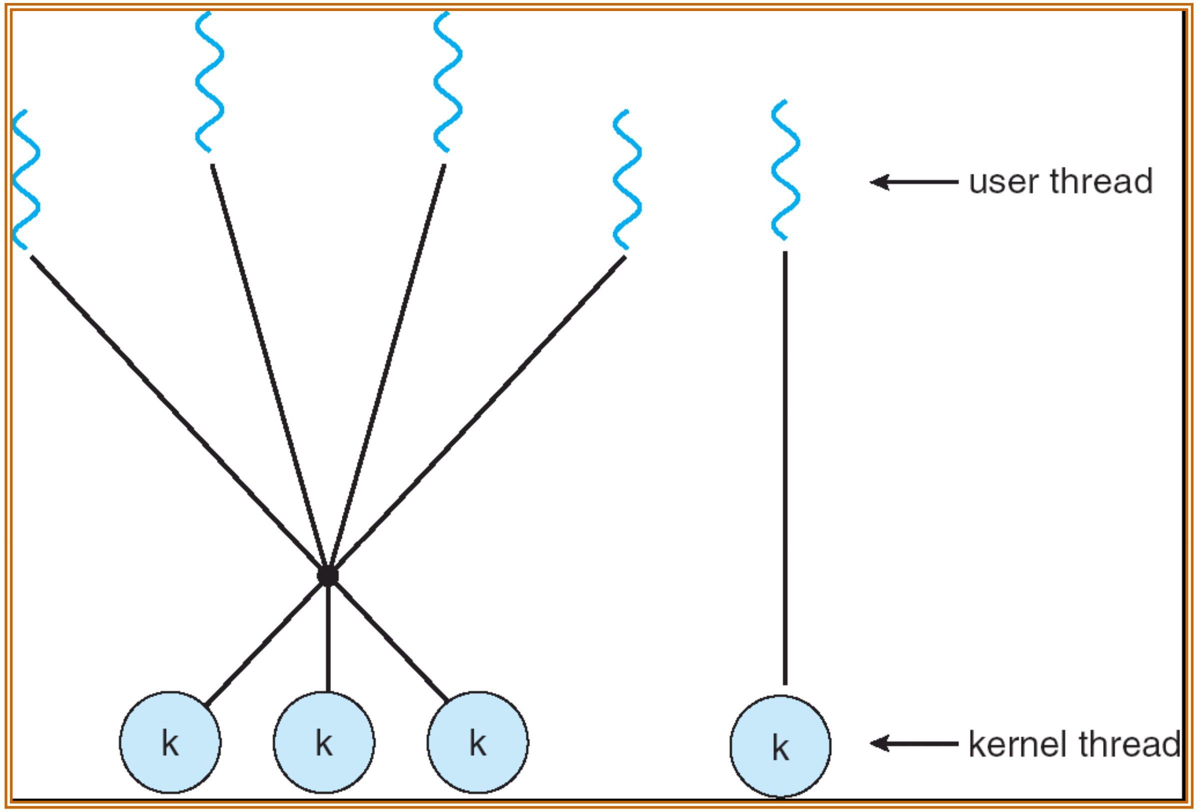


Two-level Model

- Similar to M:M, except that it allows a user thread to be **bound** to kernel thread

- Examples
  - IRIX
  - HP-UX
  - Tru64 UNIX
  - Solaris 8 and earlier

Two-level Model



Thread Libraries

- Thread library provides programmer with API for creating and managing threads
- Two primary ways of implementing
  - Library entirely in user space
  - Kernel-level library supported by the OS

Pthreads

- May be provided either as user-level or kernel-level
- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
- API specifies behavior of the thread library, implementation is up to development of the library
- Common in UNIX operating systems (Solaris, Linux, Mac OS X)

Java Threads

- Java threads are managed by the JVM
- Typically implemented using the threads model provided by underlying OS
- Java threads may be created by:
  - Extending Thread class
  - Implementing the Runnable interface

Threading Issues

- Semantics of **fork()** and **exec()** system calls
- Thread cancellation
- Signal handling
- Thread pools
- Thread specific data
- Scheduler activations

Semantics of fork() and exec()

- Does **fork()** duplicate only the calling thread or all threads?

Thread Cancellation

- Terminating a thread before it has finished

- Two general approaches:
  - **Asynchronous cancellation** terminates the target thread immediately
  - **Deferred cancellation** allows the target thread to periodically check if it should be cancelled

Signal Handling

- Signals are used in UNIX systems to notify a process that a particular event has occurred
- A **signal handler** is used to process signals
  1. Signal is generated by particular event
  2. Signal is delivered to a process
  3. Signal is handled
- Options:
  - Deliver the signal to the thread to which the signal applies
  - Deliver the signal to every thread in the process
  - Deliver the signal to certain threads in the process
  - Assign a specific threa to receive all signals for the process

Thread Pools

- The scenario of a web server.
- A separate thread to serve a request.
  - Thread (Created -> discarded) : Request (start and finish)?
  - Unlimited requests -> unlimited threads?

- Thread pools
  - Threads sit and wait for work.
  - Faster to response a request.
  - The number of threads can be dynamically adjusted.

Thread Pools

- Create a number of threads in a pool where they await work
- Advantages:
  - Usually slightly faster to service a request with an existing thread than create a new thread
  - Allows the number of threads in the application(s) to be bound to the size of the pool

Thread Specific Data

- Allows each thread to have its own copy of data
- Useful when you do not have control over the thread creation process (i.e., when using a thread pool)

Scheduler Activations

- Both M:M and Two-level models require communication to maintain the appropriate number of kernel threads allocated to the application
- Scheduler activations provide **upcalls** - a communication mechanism from the kernel to the thread library
- This communication allows an application to maintain the correct number kernel threads

Operating-system Example

- Explore how threads are implemented in Windows XP, Linux, Solaris systems.

Pthreads

- a POSIX standard (IEEE 1003.1c) API for thread creation and synchronization.
- API specifies behavior of the thread library, implementation is up to development of the library.
- User-level thread library
- Common in UNIX operating systems.
- pthread_create(), pthread_exit(), pthread_join()

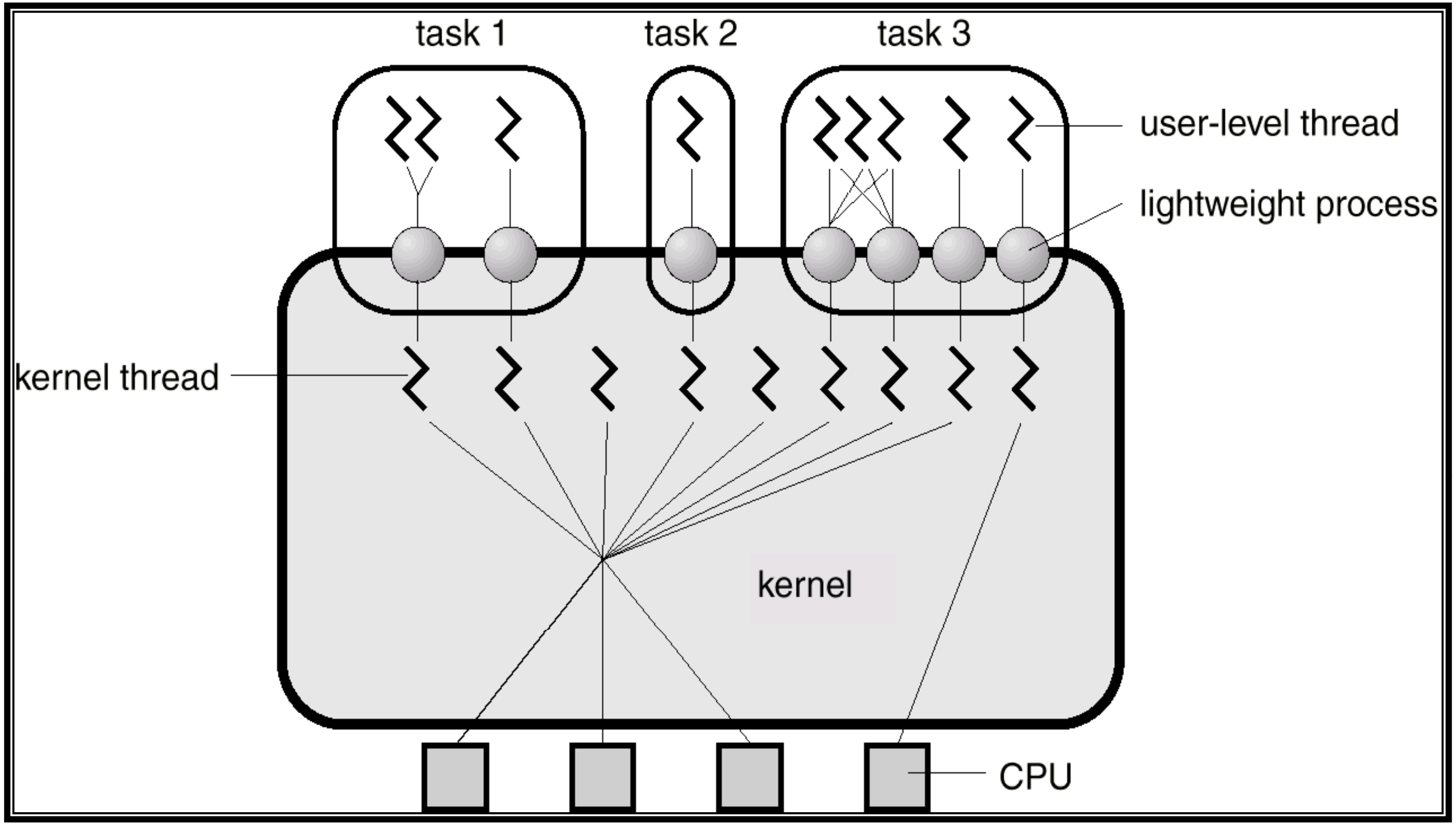
Solaris 2 threads

- Lightweight processes (LWPs)
  - Between user- and kernel- threads.

- Each process contains at least one LWP.
- Each LWP has a kernel-level thread.

- A bound user-level thread
  - Permanently attached to an LWP. (quick response time)
- An unbound thread
  - Multiplexed onto the available LWP pool.

Solaris 2 threads



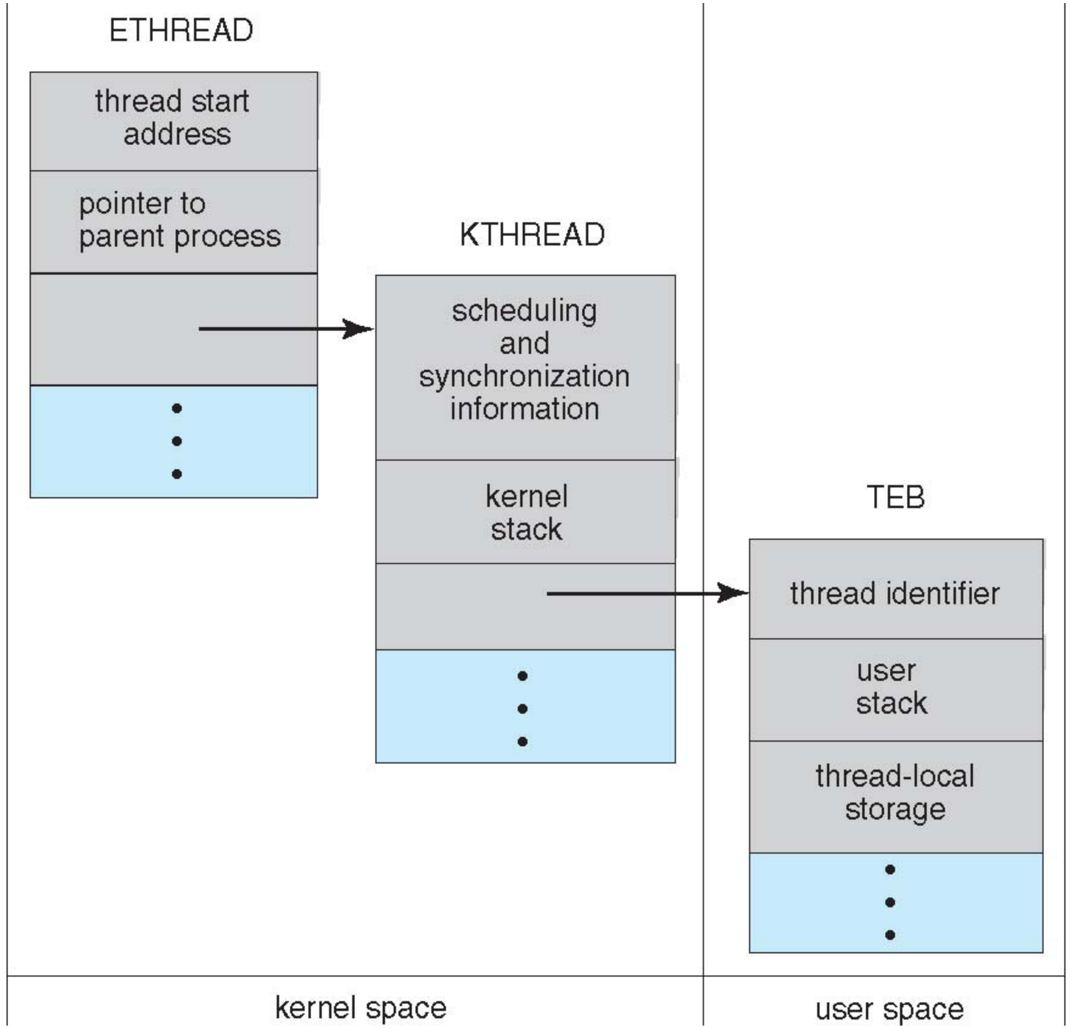
Solaris 2 threads (cont.)

- User-level thread are scheduled and switched among the LWPs by thread library.
- The thread library dynamically adjusts the number of LWPs.
  - Creates another LWP if all LWPs in a process are blocked
  - Deletes unused LWPs (about 5 minutes)
- User-level thread: thread ID, register set, stack, priority..
- LWP: a register set (for its running user-level thread), misc. info.
- Kernel thread: stack, kernel registers, a pointer to the LWP, priority and scheduling info.

Windows XP Threads

- Implements the one-to-one mapping
- Each thread contains
  - A thread id
  - Register set
  - Separate user and kernel stacks
  - Private data storage area
- The register set, stacks, and private storage area are known as the **context** of the threads
- The primary data structures of a thread include:
  - ETHREAD (executive thread block)
  - KTHREAD (kernel thread block)
  - TEB (thread environment block)

Windows XP Threads



Linux Threads

- Linux refers to them as *tasks* rather than *threads*
- Thread creation is done through **clone()** system call
- **clone()** allows a child task to share the address space of the parent task (process)

END OF CHAPTER 4